Research Article

Feasible Classification of Magnetohydrodynamic (Mhd) Generating Power Plant

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Abstract:- **This paper reviews the current status and classification of MHD generating plants with the view of determining the commercial viability of different MHD generating plants. The techniques which are vital for successful operation of the plant are discussed. This paper also attempts to investigate recent development in the field of MHD electric power plant generation and identifies the problem areas that require research and development efforts in order to achieve the commercial viability of the MHD system.**

Keywords: **Open cycle, hybrid, closed cycle, Lorentz force**

I. INTRODUCTION

The rapid growth of civilization and sophistication has triggered ever-increasing demand for energy. An energy-deficient society is weak and cannot make tangible economic advancement. Electrical energy has captured the highest level of energy hierarchy. Basically, the electrical energy propels the wheels of progress that moves at accelerating pace [1]. More than 80% of the generated electric energy is powered by fossil fuels. In fact, the entire world is threatened by this ugly trend because of rapid depletion of fossil fuels, and there is premonition that the fossil fuel will run out if not checked. Moreover, environmental pollution produced by fossil fuel-fired power plants has hazardous effects on human being, socio-economic development and increases global warming. Despite the above challenge, fossil fuel-fired generating plants have low energy conservation efficiency, not more than 35%- 40%. Hence, there is need for intensive research to improve the thermal efficiency of fossil fuel-fire turbine units [2] [3].

Presently, the search for a dependable alternative energy mix has become a global issue, which this study attempted to explore. Magnetohydrodynamic (MHD) power generation is deemed the most appropriate and unique method of power generation that can overcome the shortcomings of thermal generating plants.

The MHD power generation technology (MHD) entails the production of electrical power by means of passing high temperature conducting plasma through intense magnetic field. The MHD power generation has important role in the socioeconomic development of the nation as well as providing dependable solution to the present power crisis in many nations of the world. Efficiency is very vital in the design and establishment of thermal engines and power plant. The efficiency of all modern thermal power generating system lies between 35-40% as they have to reject large quantities of heat to the environment [4] [5]. There is need to improve this efficiency level in all other thermal conventional power plants like gas and oil turbine plants, nuclear power plant and hydro-electric power plant. MHD power plant have overall efficiency of 55%-60%, but efficiency of 80% or more can be achieved through the recent research and development programme or by utilizing superconducting magnets. So, MHD power plants have high efficiency if compared with thermal plants and orther non conventional methods of electric power generation such as wind, solar, tidal and geothermal, which have maximum efficiency of 35%. With the present research and development programmes, the MHD generator can be used not only for commercial power generation but also for so many other applications. The MHD generation will reduce the cost of generating electricity and save billions of dollars on fossil fuel prospects.

II. OBJECTIVES OF THE STUDY

This research work attempts to:

1. Provide dependable alternative electric power generating mix.
2. Reduce or eliminate depletion of fossil fuels.
3. Provide a solution to the unpalatable constant scenario of atmospheric and environmental pollution due to fossil fuel-fired generating plants.

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4. Survey the economic potentialities of MHD plant and the possibility of establishing MHD electric power plant.
5. Devise feasible technology for the establishment of MHD electric power plant.

III. PRINCIPLES OF MHD OPERATION

The MHD generator is similar to that of rocket engine but surrounded by intense magnet that produces the external magnetic field. In an MHD electric generation, the hot gas from the combustion chamber is accelerated by a nozzle and injected into the magnetic channel. Once the gas is heated to the range of 2750^o K to 3000^o K and pressurized between 7 to 15 atm pressure. To ensure good performance of the MHD generator, the hot gas is seed with ionisable alkali material. A small fraction of ionizable alkali metal like cesium or potassium carbonate (or sodium) is injected in order to increase the electrical conductivity of gas to the range of 10 to 50 siemens per meter. This can be achieved by adding 1% by mass into the hot gas. Cesium has the lowest ionizing potential (3.894 electron volts), while potassium has ionising potential (4.341 electron volts) and less costly too. A powerful magnetic field is set up across the magnetic channel. While expanding in the presence of powerful magnet, and electric field is established, which acts in a direction perpendicular to both the gas flow and the magnetic field. The positive and negative ions moves to the electrodes and constitute an electric current. The walls of the channel parallel to the magnetic field serve as electrodes and enable the generator to provide direct current electricity to an external circuit.

This is basically in accordance with Faraday's law of motional electromagnetic induction. But not the usual one, in which charge flows in a conductor when time varying magnetic field is applied. Here both electrons and heavy gas particles are in thermal equilibrium due to high collision frequencies and energy transfer/collision. While in closed MHD system plasmas are thermally non-equilibrium with elevated electron temperatures in inert gas plasmas to keep sufficient conductivity but relatively low temperature with open cycle system. To achieve this we use the concept of ohmic heating under relatively low collision frequencies between electrons and ions.

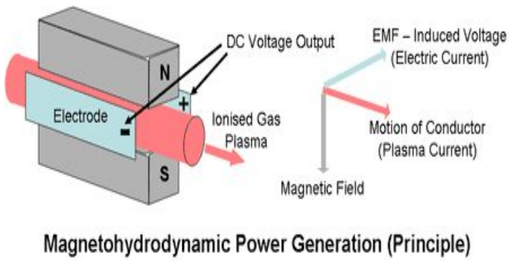

Figure 1 MHD generating principle

The power output of an MHD generator for each cubic metre of its channel volume is proportional to the product of the gas conductivity, the square of the gas velocity, and the square of the strength of the magnetic field through which the gas passes.

IV. THEORETICAL ANALYSIS OF MHD ELECTRIC GENERATION

In a typical MHD generation, let:

J = Current dens ity

σ = Electrical conductivity

U = flow velocity of motional electromotive field

B = Magnetic field density

$\vec{E}$ = Electric field

e = Electron charge

m_e = Mass of electron

Y_e = Electron mean collision frequency

μ_e = Mean electron velocity

The Lorentz force (or retard force) is given as:

$$-e\vec{u} \times \vec{B}$$

$$-\vec{U_e} \times \vec{B} \qquad \text{------------------ (1)}$$

$$-m_e Y_e (\vec{U_e} - \vec{U}) \qquad \text{-------------- (2)}$$

If the flow velocity u is much less than Ue the current density is:

$$J = -en \qquad \text{------------------ (3)}$$

$$\sigma = \frac{e^2 n_e}{m_e Y_e} \qquad \text{------------- (4)}$$

$$\mu_e = \frac{e}{m_e Y_e} \qquad \text{------------- (5)}$$

Considering the force balance and equation (1) & (4), Generalization of ohm's law gives:

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$$\vec{J} = \sigma \left(\vec{E} + \vec{U} \times \vec{B} \right) - \mu e \vec{J} \times \vec{B} \quad \text{---- (6)}$$

In equation (6), the first term describes Faraday's current, while the second term gives the hall current. The Faraday current is directly as a result of the net electric force in the plasma. The hall current and hall electric field are consequence of the electromotive force acting on the electrons as indicated in equation (1). The Lorentz force JxB acts in opposition to the gas flow and magnetic field. The Lorentz and factorial forces along the direction of the gas flow x are balanced with the aid of the pressure gradient dp/dx. Since U must be kept constant because of the motional induction, the force balance for unit volume of plasma is given as:

$$\frac{d_p}{d_x} = (\vec{J} \times \vec{B})_x - f \quad \text{-------------- (7)}$$

From the above, power generated by Lorentz force per unit volume is:

$$U\,(J \times B) \quad \text{--------------- (8)}$$

The energy dissipated as ohm's heat in the plasma is given as:

$$(J \,.\, J/\sigma) \quad \text{--------------- (9)}$$

The power output to the load is:

$$-\,(J.\,E) \quad \text{--------------- (10)}$$

So, the electrical balance obtained using equation (6) is written as:

$$-\vec{U} \,.\, (\vec{J} \,.\, \vec{B}) = -\vec{J} \,.\, \vec{E} - \frac{\vec{J}^2}{\sigma} \quad .\ (11)$$

The power balance for the plasma is given as:

$$\rho u = \frac{d_h}{d_x} = \vec{J} \times \vec{E} - q_{loss} \quad \ldots\ldots\ldots\ldots.(12)$$

Where:

P = Gas density

q_{loss} = Radiation heat loss

h = Rate of enthalpy drops per unit volume

V. TYPES OF MHD GENERATING POWER PLANTS

The classification of MHD generating power plant depends on the nature of processing and control of working fluid. Major types of MHD generating plants are:

(a) Open cycle MHD generating plant.
  - ❖ Hybrid open cycle MHD generating plant.

(b) Closed cycle MHD generating plants:
  - ➢ Inert gas closed cycle MHD generating plant.
  - ➢ Liquid metal closed cycle MHD generating plant.

5.1 OPEN CYCLE MHD GENERATING PLANT

Open cycle MHD generating plant is illustrated in figure 2. In open-cycle system of MHD power generation, the working fluid after the generation of electrical energy is discharged into the atmosphere. The fossil fuel is admitted into the combustion chamber that operates at temperature ranging from 2,000^{0}C to 2,800^0 C. The hot gases are mixed with ionized alkali metals such as cesium and potassium to increase the electrical conductivity of the hot gas. The seeded material potassium is ionizeed by the hot combustion gas. The expansion nozzle causes the hot gases to pass through the intense magnetic field at high pressure. During the movement of the gases, the positive and the negative ions flow to the electrodes and constitute direct current electricity, which is converted into alternating current electricity by means of an inverter [9] [10] [11]. The gases from the MHD are channeled into the heat exchanger. The seed material is recovered for successive use at the seed recovery apparatus. The pollutants (nitrogen and sulphur) are removed from the gases at the purifier chamber, while the clean and unharmful gases are released to the atmosphere through the stack.

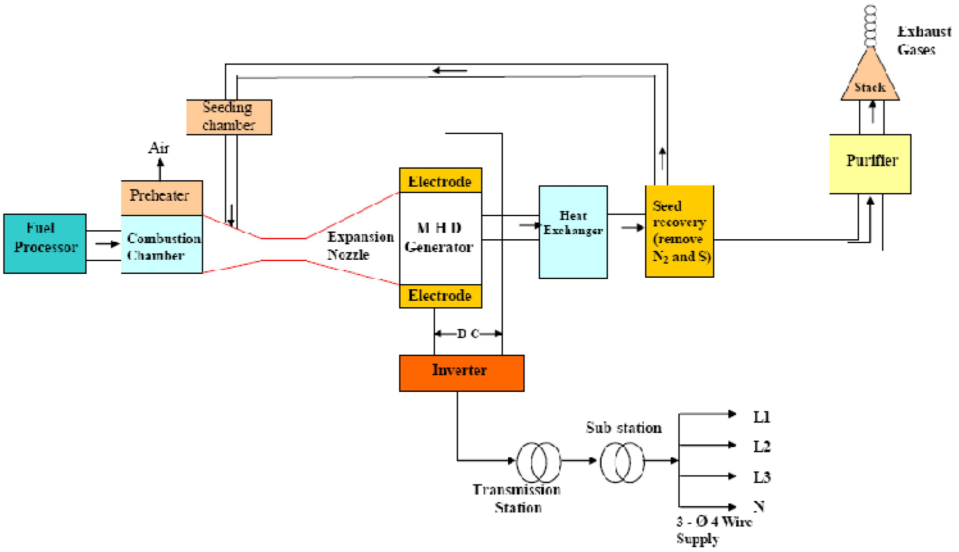

Figure 2.Schematic diagram of open cycle MHD generating plant.

5.2 *HYBRID OPEN CYCLE MHD GENERATING PLANT*

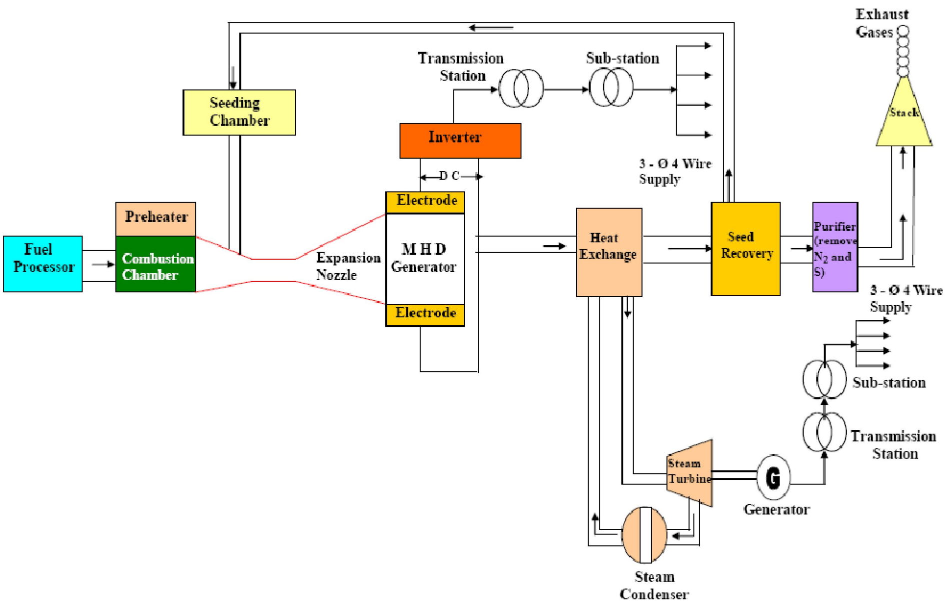

Figure 3. Schematic diagram of hybrid open cycle MHD generating plant.

Due to shortcomings of open cycle MHD generators, there is need to improve the operation of the MHD generator so that it can be suitable for commercial use and ensure efficient opration. This can be achievedby embeding a relatively complex cycle to the open cycle MHD, which is kown as hybrid or binary cycle MHD generator (figure 3).In this system, the exhaust gases from the MHD are channeled to steam turbine generator unit and steam turbine compressor for generation of additional electric power and efficient perfomance of the plant.

5.3 *CLOSED CYCLE MHD GENERATION*

In closed cycle generation, the working fluid discharged from the MHD is continuously recycled. This study investigates two basic types of closed MHD generating plants, namely:

- Inert gas closed cycle MHD generating plant.
- Liquid metal closed cycle MHD generating plant.

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5.4 INERT GAS CLOSED CYCLE MHD GENERATING PLANT

In this type of closed system, the electrical conductivity is maintained in the working fluid by ionization of the seed material. The heat from the combustion chamber is converted into working fluid, ionized gas (argon or helium), which can be seeded with cesium and circulated in closed loop. The schematic diagram of this type of closed cycle MHD generator is illustrated in figure 4. This system has three distinct but interlocking loops. The first loop is the external ***heating loop,*** which entails gasification of the fossil fuel. The released gases are burnt in the combustion chamber and channeled into the first heat exchanger (1) where they are converted into carrier gas (argon or helium). The second loop is the ***centre loop***, which comprises the hot plasma (argon or helium gases) seeded with cesium, passed through the MHD generator and second heat exchanger (2), recycle into the first heat exchanger. The third loop is the ***steam loop,*** which is used for further recovery of the heat of the working fluid. Hot fluid from the MHD is channeled into the heat exchanger (2) and converted into steam, which is utilized for driving a turbine for generating electricity and for driving a turbine that runs the plasma compressor [6] [7] [8].

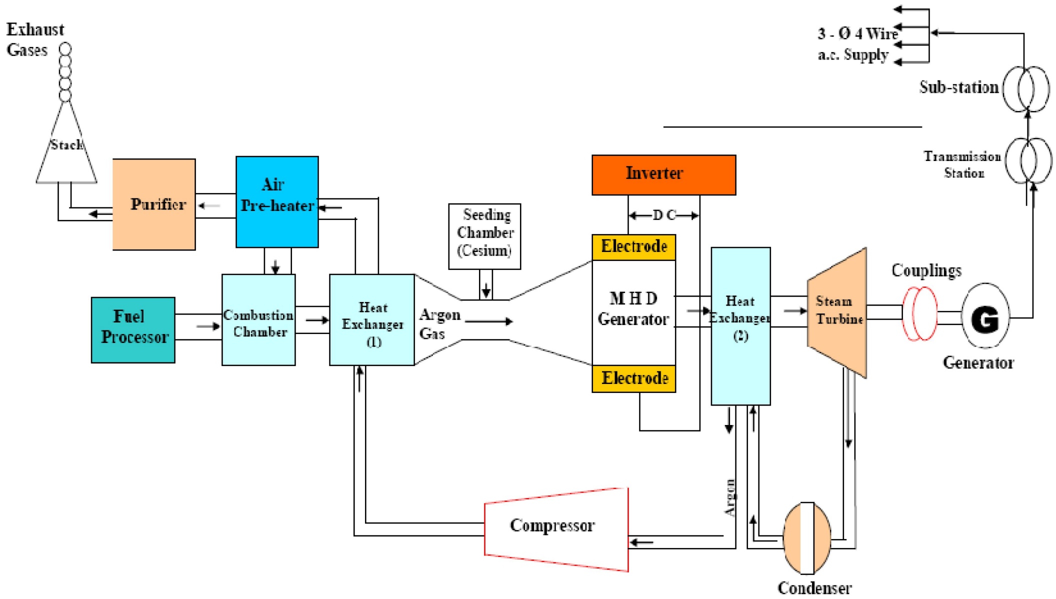

Figure 4. Schematic diagram of inert gas closed cycle MHD generating plant.

5.5 *LIQUID METAL CLOSED CYCLE MHD GENERATING PLANT.*

In this generator (figure 5), the conductivity is provided by the liquid metal. The carrier gas is pressurized and heated by passing through a heat exchanger and combustion chamber. The hot gas is then incorporated into the liquid metal usually hot sodium to form the working fluid. However, the system does not require high temperature for its operation.The working fluid is introduced into the MHD generator through a supersonic nozzle. The carrier gas then provides the required high direct velocity of the electrical conductor. After passage through the generator, the liquid metal is separated from the carrier gas. Part of the heat is channeled into the heat exchanger to produce steam for operating a turbine generator. Finally the carrier gas is cooled, compressed and returned to the combustion chamber for reheating and mixing with the recovered liquid metal for continuous recycle process.

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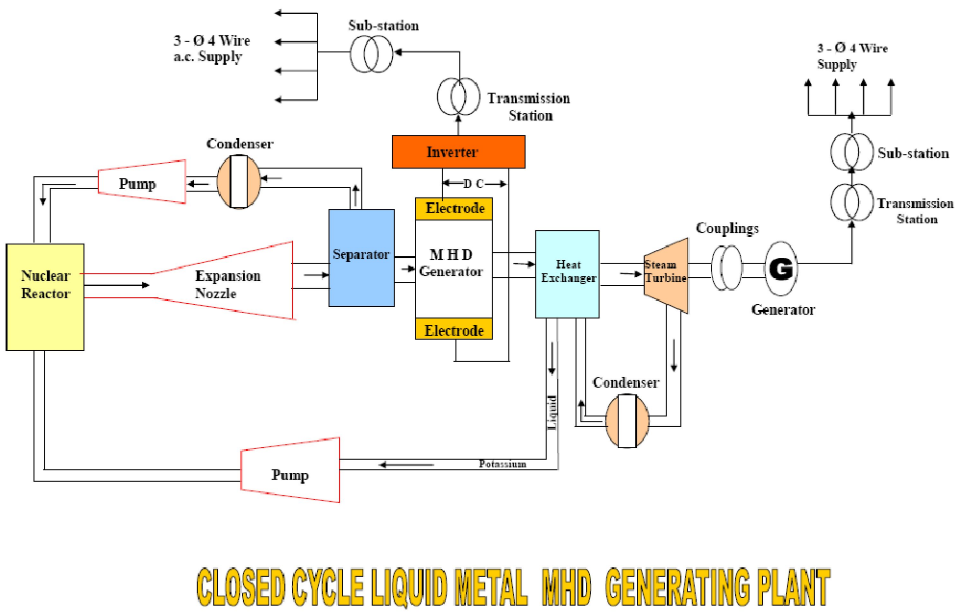

Figure 5 schematic diagram of closed cycle liquid metal MHD generating plant

VI. ADVANTAGES OF MHD GENERATING POWER PLANT

The MHD generating power plants have various advantages over the conventional methods of generating electricity as given below:

- The MHD power plants have no moving parts, therefore, more reliable than other conventional methods.
- MHD plants have high temperature requirement and high operational efficiency up to 60%.
- Closed-cycle system of MHD power generation is pollution free.
- It is possible to run the standby power plant in conjunction with MHD power generation scheme.
- The overall costs of MHD generating plant is lower than conventional power plant.
- The MHD plants reduce the depletion of fossil fuels.
- MHD plants have the ability to reach the full power level instantly.
- Reduction of energy losses due to direct conversion of heat into electricity.

VII. CONCLUSION

The solution to the insufficient electric power generation problems ravaging many countries of the world can be achieved through critical research investigations and harnessing different classifications of viable MHD generating power plants with the view of selecting suitable power plant. It is obvious that MHD generating plants will be the most efficient, effective and economical renewable and alternative energy mix for the present global power generation problem.

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